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Mercury Pollution Due to Small-Scale Gold Mining in the Philippines: An Economic Analysis

Danilo C. Israel and Jasminda P. Asirot

PHILIPPINE INSTITUTE FOR DEVELOPMENT STUDIES
Surian sa mga Pag-aaral Pangkaunlaran ng Pilipinas

This study was funded by the Economy and Environment Program for Southeast Asia (EEPSEA) and the World Bank (WB). It reviews small-scale gold mining in the Philippines and assesses mercury pollution and other development problems in the industry.

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ABSTRACT

The study reviews small-scale gold mining in the Philippines and assesses economically mercury pollution and other development problems of the industry. The end purpose is to suggest measures to address the problems and promote better environmental and overall management of small-scale mining. The study uses secondary data from mining institutions as well as primary data from key informants and small-scale gold miners and processors in the two case study sites.

INTRODUCTION

Small-scale gold mining is an activity that relies heavily on manual labor and uses simple implements and methods. Although it is a humble form of livelihood, it contributes significantly to gold production and rural employment in the Philippines.

While economically significant, small-scale gold mining has been the target of strong opposition in recent years mainly because of its various adverse environmental and social side effects. Foremost of these is mercury pollution.

BRIEF REVIEW OF LITERATURE

Numerous foreign studies already investigated the problem of mercury pollution due to small-scale gold mining, concentrating on the experience in Brazil (e.g., Veiga 1997a and 1997b, Akagi et al. 1995, Aula et al. 1995, Malm et al. 1995, Porvari 1995, Barbosa et al. 1995, Guimaraes et al. 1995, Veiga et al. 1995, Veiga and Meech 1995). High levels of mercury concentrations were found in the hair and blood samples of the miners and other affected people as well as in fish, soil sediments and forest and river ecosystems in small-scale gold mining areas of the Amazon region.

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In the Philippines, several studies also looked into mercury pollution based on the experience in Diwalwal, the largest small-scale mining site in the country (e.g. Mahinay et al. 1998, Bacani et al. 1996, Breward 1996, Balce and Cabalda 1992, Williams et al. 1995). High levels of mercury pollution were found on-site as well as in the affected places downstream. Williams et al. specifically asserted that there were already considerable mercury loads in some sectors of the Agusan River, where Diwalwal drains into, and that the water samples from the mining site itself showed higher concentrations than those in the other gold rush areas in the world.

Although studies on the impact of mercury pollution due to small-scale mining were already numerous, they were generally technical in nature. Few works touched on the economic aspects of the problem and did so only in a superficial and summary manner. So far, there is no available study that conducted an economic analysis in a more detailed and quantitative way in the Philippines or elsewhere.

OBJECTIVES AND DATA

The main objective of this study is to review small-scale gold mining in the Philippines and quantitatively assess, to the extent possible, the economic cost of mercury pollution. As a corollary goal, the study discusses the other environmental and development problems associated to the activity. The end purpose is to suggest measures to address the problems and promote better management of small-scale mining.

The study uses both primary and secondary data. The secondary sources of data were the Mines and Geosciences Bureau (MGB), World Bureau of Metal Statistics, National Statistical Coordination Board (NSCB) and the existing research literature on small-scale mining. The sources of primary data were the key informants, local government units (LGUs), and the small-scale gold miners and processors in the two case study sites who were covered by a brief survey conducted for the study.

REVIEW OF SMALL-SCALE GOLD MINING IN THE PHILIPPINES

World and Philippine Gold Production

The world production of gold has been growing over the years (Table 1). Volume increased from about 1.2 thousand metric tons in 1980 to

2.3 thousand metric tons in 1997. The top world producers of gold for the 1980-1997 period were South Africa which contributed 34.54 percent to the average total production annually, USSR which added 14.39 percent, and the US which registered 11.07 percent.

Following the international trend, the production of gold in the Philippines has also been increasing over time (Table 1). Volume rose from about 20 metric tons in 1980 to 33 metric tons in 1997. The local production was only a small percentage of world production, however. On average yearly, the gold output of the country was only 1.57 percent of the world production for the 1980-1997 period.

While local production was low relative to world production, gold was the number one mineral produced by the Philippines in value terms (Table 2). From 1980 to 1997, gold contributed an annual average of 32.54 percent to the total value of mineral production, followed by copper concentrate, sand and gravel, salt, and coal which share 25.98 percent, 13.28 percent, 9.05 percent and 4.71 percent, respectively.

Philippine exports of gold have been growing over the years, in volume and value terms (Table 3). Volume increased from about 12.7 metric tons in 1980 to 15.7 metric tons in 1997. FOB value rose from about P1.78 billion in 1980 to P5.0 billion in 1997.

The top importing countries of Philippine gold for the 1980-1997 period were Japan, followed by the United Kingdom, United States, Taiwan, South Korea, China and North Korea (Table 4). Exports to Japan have been decreasing on average over the years. In contrast, exports to the United Kingdom have been rising. In recent years, exports to the United States and Taiwan have ceased while exports to China and North Korea have been intermittent.

For the 1980-1997 period, the gross value added (GVA) in mining and quarrying was only 1.56 percent of the Gross National Product (GNP) annually on average, at constant prices (Table 5). The GVA in gold mining alone was 0.60 percent of GNP on average yearly.

The Philippine Small-Scale Gold Mining sector

There are two kinds of ore reserves relevant to small-scale gold mining: indicated reserves and inferred reserves (Javelosa 1997). Indicated reserves are those for which tonnage and grade are computed partly from specific measurements, samples or production data, and

Table 1. World annual gold production, by country, 1980-1997 (in metric tons)

Year	South Africa	USSR	United States	Philippines	Others	Total
1997	493	237	338	33	1,166	2,266
1996	495	214	312	30	1,080	2,130
1995	522	213	313	27	1,021	2,097
1994	584	229	326	27	974	2,140
1993	620	236	331	25	914	2,125
1992	609	226	330	26	935	2,125
1991	601	220	294	26	905	2,046
1990	601	302	295	25	864	2,086
1989	606	304	201	30	718	1,858
1988	619	278	201	30	664	1,792
1987	602	260	155	33	552	1,602
1986	638	273	116	35	477	1,540
1985	671	272	76	33	430	1,481
1984	680	269	63	26	382	1,420
1983	680	268	61	25	359	1,392
1982	664	266	46	26	330	1,331
1981	656	262	43	24	272	1,256
1980	672	258	30	20	207	1,188
Average	612	255	196	28	680	1,771
Percent	34.54	14.39	11.07	1.57	38.43	100.00

Note: Data for USSR for the years 1992-1997 were only for Russia, Armenia, Georgia, Kazakhstan, Kyrgyzstan, Tajikstan, Ukraine and Uzbekistan.
Sources: World Bureau of Metal Statistics (January 1987-December 1998) and Mines and Geo-Sciences Bureau (1980-1997).

Table 2. Mineral production of the Philippines, 1980-1997 (in million pesos)

Year	Gold	Copper Concentrate	Sand and Gravel	Salt (from sea water)	Coal	Others	Total
1997	9,909	2,792	10,062	7,250	1,187	1,880	33,080
1996	9,855	3,364	8,733	6,078	956	2,093	31,079
1995	8,484	5,786	6,601	3,851	1,266	2,013	28,001
1994	8,966	5,521	4,050	3,542	1,298	1,209	24,586
1993	7,926	6,262	3,389	3,128	1,582	1,152	23,439
1992	7,189	6,641	2,400	2,194	1,828	4,411	24,664
1991	8,177	7,677	2,257	2,178	1,421	2,349	24,059
1990	7,116	7,891	2,194	1,803	1,060	2,305	22,369
1989	7,925	7,948	2,072	1,801	1,042	2,379	23,168
1988	8,844	7,953	1,207	443	1,028	2,285	21,760
1987	9,352	6,141	1,392	413	931	1,277	19,506
1986	8,395	5,461	1,221	391	1,149	3,421	20,037
1985	6,088	5,630	1,071	365	1,509	6,323	20,987
1984	4,773	4,970	1,142	341	1,134	5,163	17,522
1983	3,822	4,047	1,022	318	393	4,039	13,641
1982	2,651	3,446	858	219	189	3,937	11,301
1981	2,642	3,782	691	213	64	4,470	11,862
1980	2,785	4,409	613	204	59	4,750	12,821
Average	6,939	5,540	2,832	1,930	1,005	3,081	21,327
Percent	32.54	25.98	13.28	9.05	4.71	14.45	100.00

Source: Mines and Geosciences Bureau (1980-1997).

Table 3. Philippine gold exports, 1980-1997

Year	Quantity (in metric tons)	FOB Value (in million pesos)
1997	15.7	5,014
1996	10.9	3,533
1995	12.3	3,620
1994	13.9	4,407
1993	13.4	3,979
1992	13.6	3,740
1991	4.7	1,922
1990	6.1	1,597
1989	6.9	1,904
1988	6.8	2,076
1987	6.5	1,903
1986	6.8	1,580
1985	7.4	1,366
1984	9.1	1,790
1983	11.4	1,367
1982	15.5	1,594
1981	14.7	1,694
1980	12.7	1,785
Average	**10.5**	**2,493**

Source: Mines and Geosciences Bureau (1980-1997).

projection for a reasonable distance or geologic evidence. Inferred reserves are those for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit.

In 1992, the Philippines had an estimated 60.8 million metric tons of indicated reserves and 180.4 million metric tons of inferred reserves (Table 6). The indicated reserves had a metal content mean of 87.59 metric tons and appeared to be profitable for small-scale operations. In contrast, the inferred reserves had a metal content mean of 0.58 metric tons suggesting that they were not feasible for small-scale operations. The largest indicated and inferred reserves were found in the Cordillera Autonomous Region (CAR) while the smallest were in Region VI.

Small-scale gold mining covered a total claim area of about 4,939 hectares in 1992 (Table 7). The largest claim areas were in CAR, Region XI and Region XII. Region VI had the smallest claim area followed by Region X and Region IV. There were 135 small-scale gold mining sites in

Table 4. Philippine gold exports, by country of destination, 1980-1997 (kilograms)

Year	Japan	United Kingdom	United States	Taiwan	South Korea	China	North Korea	Others	Total
1997	3,813	11,920	-	-	-	-	14	-	15,747
1996	3,770	7,104	-	-	-	14	-	-	10,888
1995	5,028	6,913	-	-	-	80	-	307	12,328
1994	4,695	8,817	-	-	24	15	-	313	13,864
1993	4,562	8,695	-	-	54	-	-	108	13,419
1992	5,866	6,096	-	-	147	51	10	1,394	13,564
1991	4,644	-	-	-	46	57	-	-	4,747
1990	5,888	42	136	-	83	-	-	-	6,149
1989	6,737	44	-	15	74	-	-	30	6,900
1988	6,354	6	-	118	167	-	-	162	6,807
1987	5,993	52	-	-	329	130	-	9	6,513
1986	6,001	18	-	22	81	146	-	508	6,776
1985	6,403	57	-	89	173	501	44	127	7,394
1984	6,764	70	618	1,026	123	244	254	39	9,138
1983	7,770	4	1,416	1,005	1,016	150	29	27	11,417
1982	10,636	35	1,963	1,321	1,028	371	103	77	15,535
1981	9,215	52	2,513	1,508	875	217	55	278	14,713
1980	9,384	25	1,096	1,017	739	71	54	361	12,747
Average	6,307	2,988	1,290	680	331	157	70	267	10,480
Percent	73.62	0.20	8.60	7.98	5.80	0.96	0.42	2.88	100.00

Source: Mines and Geosciences Bureau (1980-1997).

Table 5. Philippine gross national product (GNP), gross value added (GVA) of mining and quarrying and GVA of gold mining, 1980-1997(million pesos, constant 1985 prices)

YEAR	GNP	GVA of mining and quarrying	Percentage of GVA of mining and quarrying to GNP	GVA of gold mining	Percentage of GVA of gold mining to GNP
1997	930,363	10,338	1.11	4,182	0.45
1996	884,226	10,166	1.15	3,948	0.45
1995	824,525	10,035	1.22	3,585	0.43
1994	786,136	10,763	1.37	4,185	0.53
1993	746,921	11,571	1.55	4,157	0.56
1992	731,396	11,495	1.57	4,584	0.63
1991	720,218	10,770	1.50	4,862	0.68
1990	716,929	11,091	1.55	4,800	0.67
1989	684,231	11,389	1.66	4,915	0.72
1988	644,229	11,704	1.82	4,701	0.73
1987	600,907	11,232	1.87	5,394	0.90
1986	571,492	12,313	2.15	6,445	1.13
1985	551,428	11,893	2.16	5,390	0.98
1984	592,694	8,959	1.51	2,876	0.49
1983	652,097	9,244	1.42	2,538	0.39
1982	641,510	9,165	1.43	2,469	0.38
1981	626,321	9,350	1.49	2,231	0.36
1980	605,687	9,128	1.51	1,843	0.30
Average	**695,073**	**10,589**	**1.56**	**4,061**	**0.60**

Source: National Statistical Coordination Board (1993 and 1999).

Table 6. Estimated geologic mineral reserves of the small-scale mines in the Philippines, by region, 1992

Region	Indicated Reserve			Inferred Reserve		
	Volume 000 (m^3)	Reserve 000 (MT)	Metal Content mean (MT)	Volume 000 (m^3)	Reserve 000 (MT)	Metal Content mean (MT)
CAR	79,214	21,050	9.55	237,534	62,939	0.05
I	8,593	2,276	11.64	25,780	6,830	0.05
II	19,999	5,297	8.10	59,999	15,895	0.04
III	19,142	5,072	0.07	49,927	13,229	0.12
IV	3,498	924	0.16	10,498	2,780	0.06
V	20,811	5,511	17.46	62,436	16,539	0.05
VI	312	82	2.10	937	248	0.01
VII	20,781	5,505	3.95	62,343	16,515	0.05
VIII	12,475	3,304	3.56	37,427	9,913	0.05
IX	21,439	5,678	3.82	64,313	17,040	0.03
X	2,466	651	0.52	7,404	1,955	0.05
XI	67,500	17,884	11.17	202,500	53,657	0.04
XII	32,500	8,611	25.04	97,500	25,833	0.03
Total	**229,516**	**60,795**	**87.59**	**681,064**	**180,434**	**0.58**

Source: Javelosa (1997).

Table 7. Small-scale gold mining claim areas and sites in the Philippines, by region, 1992

Region	Claim Areas		Sites	
	(Ha)	Percent	Number	Percent
CAR	1,266.89	25.65	39	28.89
I	137.50	2.78	5	3.70
II	320.00	6.48	9	6.67
III	306.28	6.20	3	2.22
IV	56.00	1.13	8	5.93
V	333.00	6.74	16	11.85
VI	5.00	0.10	2	1.48
VII	332.50	6.73	6	4.44
VIII	199.62	4.04	10	7.41
IX	343.00	6.94	9	6.67
X	39.50	0.80	10	7.41
XI	1,080.00	21.87	11	8.15
XII	520.00	10.53	7	5.19
Total	**4,939.29**	**100.00**	**135**	**100.00**

Source: Javelosa (1997).

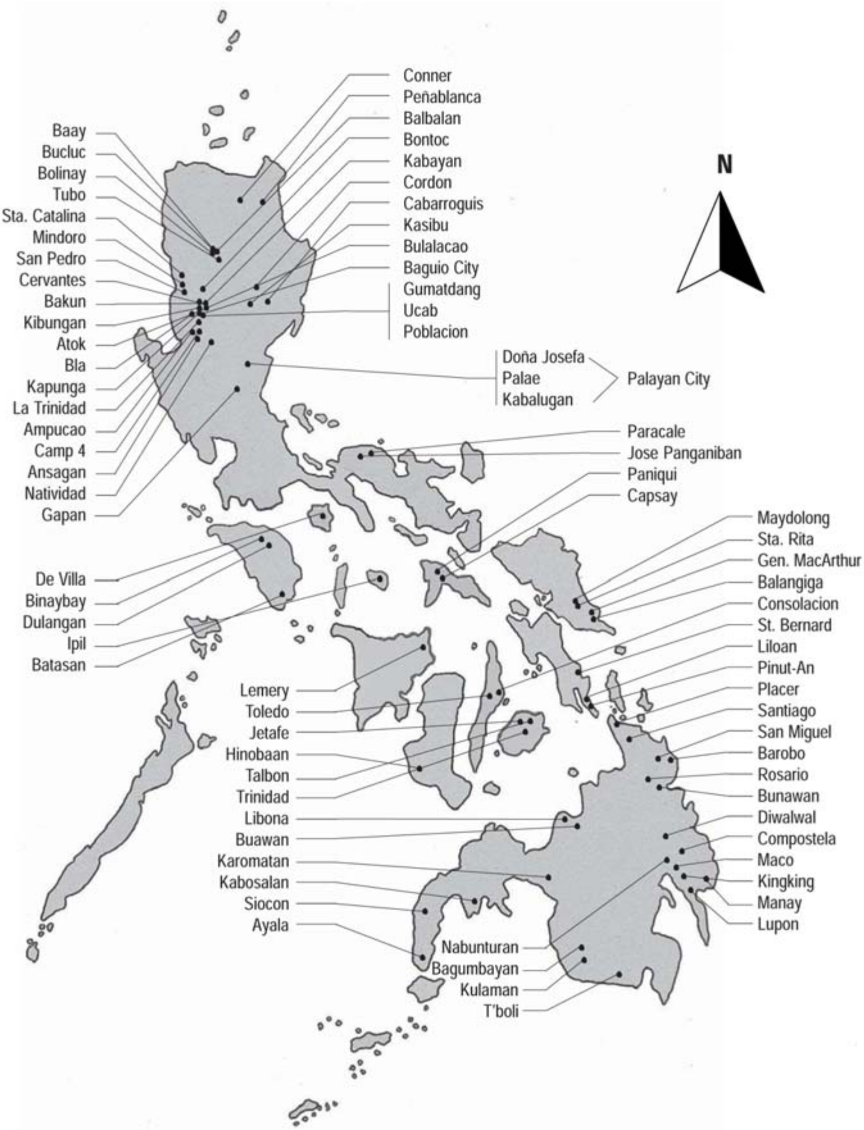
all these areas, the most number of which were found in CAR, Region V and Region XI while the least number were found in Region III, Region I and Region VII. The largest sites in terms of claim area were in the provinces of Sultan Kudarat, Davao del Norte and Nueva Ecija while the smallest were in Agusan del Norte, Ilocos Sur, Bohol, Surigao del Norte, Agusan del Norte and Cebu. The distribution of the different small-scale gold mining areas is shown in Figure 1. Some of the areas in the map have more than one mining site.

Most of small-scale gold mining in the Philippines was operated without license and, therefore, illegal. Because of this, accurate production data were hard to find and discrepancies in estimates provided by the few secondary sources available expectedly occur. The estimated production for 1992 in small-scale gold mining from both seasonal and continuous operations, excluding alluvial gold panning, was at 6,826 kilograms (NSCB 1999, Santelices 1997). This means that underground small-scale gold mining contributed around 25 percent of the total gold production (computed from Table 1). This contribution was certainly large coming from a non-mechanized and generally artisanal form of mining activity.

Foreign studies cited much higher production levels for small-scale mining in the Philippines. Stewart (1994) estimated that from 1985 to 1986, about 10,000 tons of gold were produced by the activity. Dhar (1994) reported even higher figures. Quoting local sources, he asserted that about 150 tons of gold were produced by local small-scale mining annually. However, only 25 to 26 tons of these eventually find their way to the Central Bank because of pilferage into the black market. These higher figures should be treated with caution as they practically suggest that overall gold mining in the Philippines was dominated by small-scale activities.

The exact number of small-scale miners in the country is also not known. Bayle (1995) estimated that 250,000 people were directly engaged in the activity while Dhar (1994) figured that about 400,000 to 500,000 people were in one or another involved in it, including those working in the backward and forward linkages of the industry. While the figures were rough, they manifest the great importance of small-scale mining as an employment haven in the rural upland areas.

Figure 1. Distribution map showing different small-scale gold mining areas in the Philippines



Small-scale mining is not an important public revenue-generating sector for the government at present because of its largely illegal nature. Viewed in a more positive light, the activity should become a solid tax base when fully licensed, given the large number of people and economic activities dependent on it.

Laws and Institutions in Small-Scale Mining

Laws

The earliest mining law in the Philippines was Commonwealth Act 137 promulgated in 1936. This legislation had no separate provision for small-scale mining since the activity was not practiced extensively then. It took effect for many years until the martial law era when it was amended through Presidential Decree (PD) 463, otherwise known as the Mineral Resources Decree of 1974. Like its predecessor, this legislation did not have separate provisions for small-scale mining.

In 1984, PD 899 established small-scale mining as a new dimension in mineral development and defined it as a specific activity. Succeeding orders based on this law stipulated, among others, the rules and regulations governing the granting of small-scale mining permits and ordered the selling of the gold recovered through the activity only to the Central Bank and its authorized representatives.

During the term of President Corazon C. Aquino, the Congress of the Philippines passed Republic Act (RA) 7076 or the People's Small-Scale Mining Act of 1991. Among its important provisions, this law established the People's Small-Scale Mining Program and described the small-scale mining areas that can be opened under it.

During the administration of President Fidel V. Ramos, RA 7942 or the Philippine Mining Act of 1995 was passed. This law stipulated that small-scale mining will continue to be governed by the provisions of RA 7076 and PD 1899 and their implementing rules and regulations.

Institutions

Prior to PD 899 in 1984, no government agency managed small-scale mining since it was not described as a formal economic sector yet. Those engaged in the activity did so without any government interference. With the passing of the law, the MGB was given the authority to administer small-scale mining.

In the early 90's, the administrative supervision of small-scale mining remained with the MGB under RA 7076. Later on, through a series of administrative orders, the authority to grant small-scale mining permits was devolved to governors or mayors, upon clearance from the regional offices of the Department of Environment and Natural Resources (DENR), under which the MGB administratively falls.

As part of its current reorganization, the MGB created the Small-Scale Mining Section under its Mining Environment and Safety Division. The functions of this new unit include the environmental assessment of small-scale mining areas and policy formulation related to the environment and small-scale mining activities. Figure 2 illustrates the organizational chart of the MGB and the location of the Mines and Environment and Safety Division in the agency.

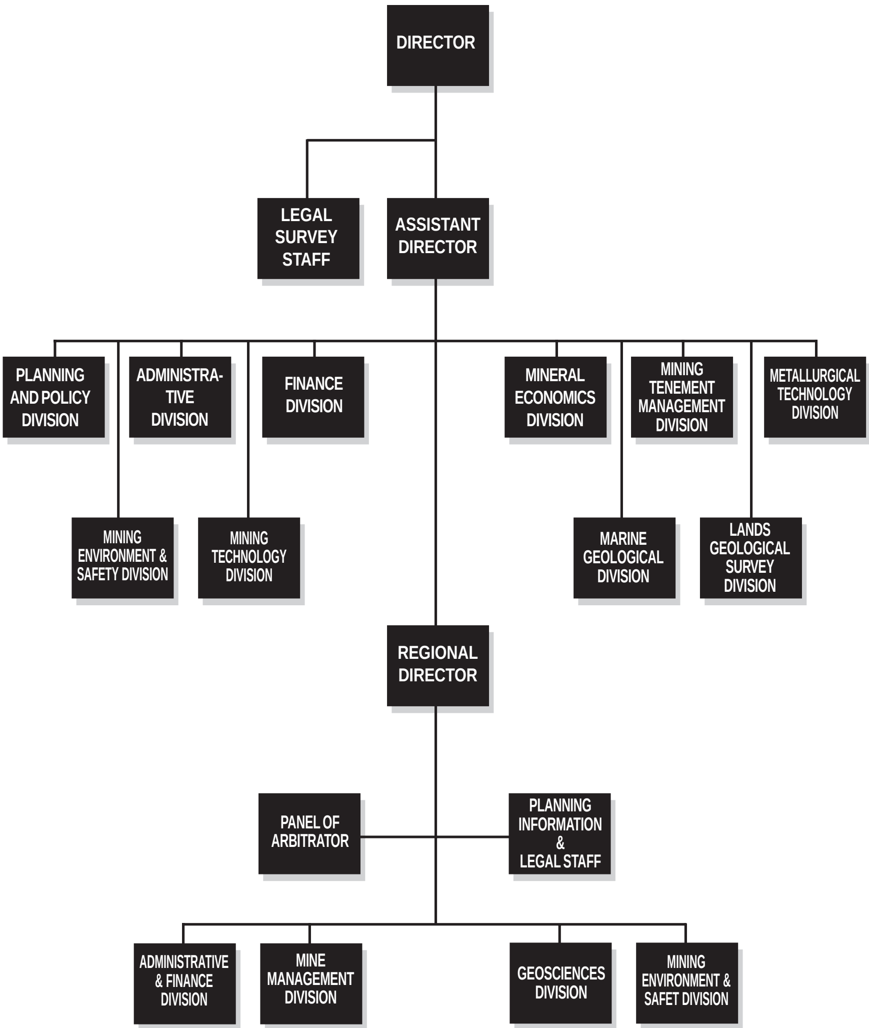
MERCURY POLLUTION DUE TO SMALL-SCALE MINING

The Amalgamation Method of Gold Processing

Mercury gets into the picture in small-scale mining because it is the main agent used to separate the gold from the mined ore employing the amalgamation method of processing. Amalgamation is popular in small-scale mining areas since it is simple to apply and requires relatively low investment.

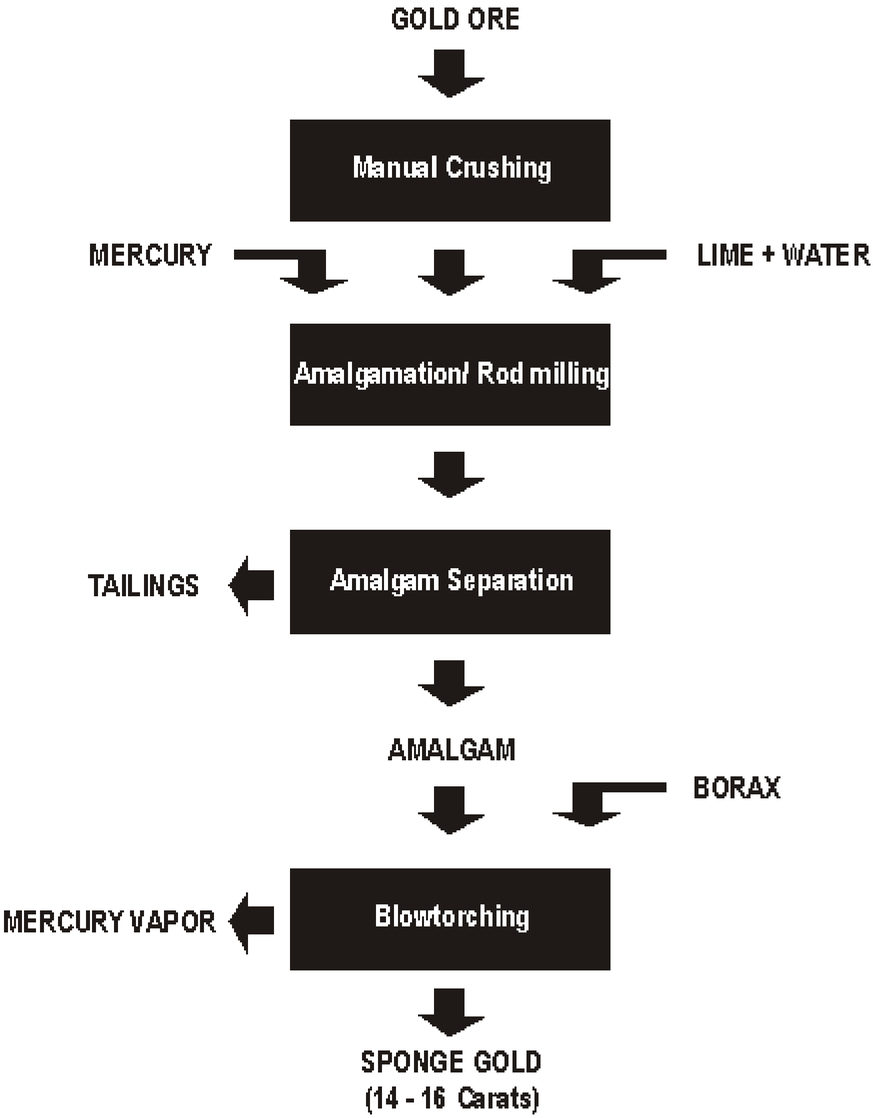
Figure 3 illustrates the amalgamation method of gold processing. First, the ore coming from the mine is crushed manually, usually by sledgehammers, to loosen it up before the broken parts are classified into different particle sizes. Then the particles are fed into a facility for grinding ore called rod mill or ball mill. Lime and water is added to the ore and grinding commences. After several hours, the mill is turned off and mercury is mixed with the fine ore. Then, the mill is turned on again for a few more hours to make the gold element attach itself to the mercury. Afterwards, the milled ore is placed in a large basin and the heavy metal alloy is allowed to settle down. Water is again added to the milled ore to remove the slurry, leaving behind the amalgam or the mercury loaded with gold. This separation of the amalgam from the slurry results to the production of mine tailings.

Figure 2. The Mines and Geoscience Bureau organizational chart



Source: Mines and Geosciences Bureau files (1998).

Figure 3. Diagram of the amalgamation process in small-scale mining



Source: Mines and Geosciences Bureau field report files (1996)

The amalgam separated from the slurry is then collected and placed in a fine cloth. This is then squeezed to remove the excess mercury. The amalgam produced so far still contains traces of mercury in it. To refine it, Borax is added to the amalgam as a cleaning agent to remove impurities. After cleaning, the amalgam is then blowtorched in a circular clay pot to separate the gold from the remaining mercury. The final product is 14 to 16 carat of sponge gold.

Amalgamation, up to the point where the impure amalgam is produced, is done by the miners themselves or the workers in rod mills or ball mills. Blowtorching is also done by them and by workers in gold shops.

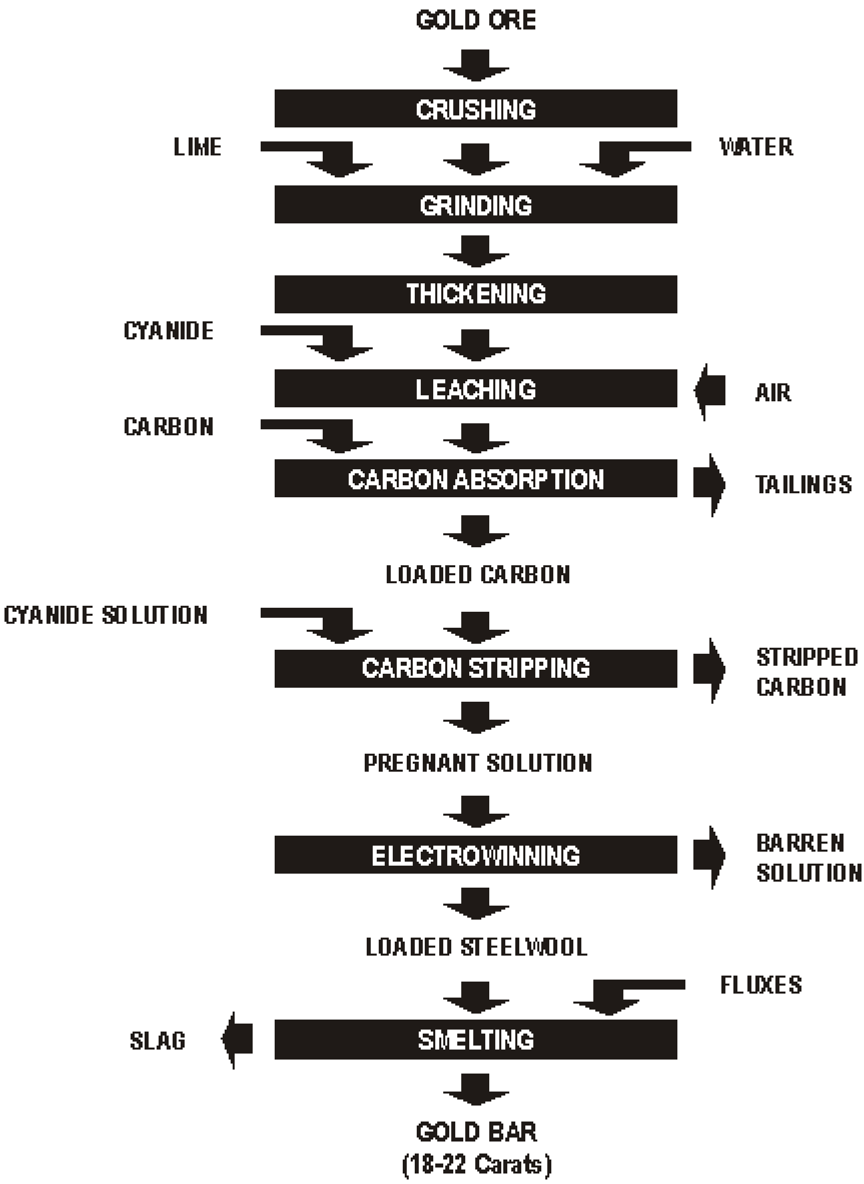
The Carbon-in-Pulp (CIP) Method of Gold Processing

Gold can also be processed using the CIP method. This method can process the slurry produced by amalgamation or the milled ore coming from the rod and ball mills directly. However, CIP is not used widely in small-scale mining because of the high cost of investment that it requires. The CIP method of gold processing is illustrated in Figure 4.

The CIP process starts with the crushing of the ore. After crushing, the ore is placed in a rod mill or ball mill and added with lime and water then grinded until it turns into fine ore. This material is then transferred to a container called repulper where more lime is added to it and further grinding and thickening is done. (Attached to the repulper is a mercury trap which collects the remaining mercury when slurry from amalgamation is processed.) The resulting mixture (referred to as pulp) is then transferred to the leaching tank. In the tank, cyanide is added to the pulp which is then agitated further in a series of tanks. After 48 hours, activated carbon is added to the last tank to counter the flow of the pulp and collects the gold in the mixture. The loaded carbon is then harvested through airlift using an air compressor while the remaining pulp now becomes mining wastes and disposed off to the tailings pond.

The loaded carbon is then placed in the carbon column after washing with water and/or acid compound. Then, cyanide solution is again added and carbon stripping is done through heating at temperature of about 95 to 100 degrees Celsius. The resulting material so far is the pregnant solution. The overflow of this solution is further made to pass through the electrowinning cell, which is composed of an array of an-

Figure 4. Diagram of the carbon-in-pulp process in small-scale mining



Source: Mines and Geosciences Bureau fields report files (1996) ode and cathode made up of steel plate and steel wool. This process separates the gold from the barren solution as the gold attaches to the cathode during this process producing loaded steelwool. The cathode is then treated with acid to produce the sludge gold. Finally, smelting is done where fluxes are added to the sludge gold and melted in the furnace. The resulting output is then molded into gold bars of 18 to 22 carats.

The Health Impact of Mercury Pollution

There are different ways by which the amalgamation method of gold processing causes mercury pollution. One way is when mercury is unintentionally spilled into the ground because of careless handling. Another is when mercury is discharged together with other wastes into inadequate tailings ponds, or worse, thrown away directly into rivers and waterways. Still another way is when vaporized mercury is released into the atmosphere when the amalgam is blowtorched and refined.

Once in the environment, mercury is dangerous because of its potential adverse impact on human health. In the case of water pollution, part of the mercury discharged into rivers and waterways is transformed into methylmercury eaten by aquatic species and in turn consumed by people. Once inside the human body, mercury could trigger neurological disturbances as well as problems in the reproductive and other body organs (Viega 1997a). The likely symptoms are visual constriction, numbness of the extremities and the impairment of hearing, speech and gait.

The release of mercury into the atmosphere during blowtorching also puts to risk human health. The activity is usually done in open containers and closed houses so the inhalation of vaporized mercury is highly possible among the people conducting it and those close by. The long-term effect of this type of exposure is the impairment of the metabolism of the human nervous system that eventually leads to certain neurobehavioral disturbances. The visible symptoms are the exhibition of exaggerated emotional responses and muscular tremors and gingivitis.

CASE STUDIES

Although mercury pollution in Diwalwal has been documented, a study of other mine sites is needed to confirm the pervasive existence of the problem in small-scale mining. Diwalwal at present has a large presence of medium and even large-scale mining operations that make it hardly representative of all small-scale mining areas. Two small-scale mining sites were selected as case study areas: Panique in Aroroy, Masbate and Tugos, Paracale, Camarines Norte. These were average small-scale mining sites in terms of area and number of miners involved. Furthermore, the mining operations there were generally small-scale in nature.

Diwalwal is profiled first because it is the most controversial small-scale mining area in the country, not only in terms of mercury pollution but also of other development problems.

Diwalwal

The map of the Philippines showing the newly created province of Compostela Valley and the map of this province indicating the municipality of Monkayo and the barangay of Diwalwal are shown in Figure 5. The official name of the barangay is actually Mt. Diwata but was renamed to Diwalwal by folklore.

In 1997, Diwalwal had a population of 9,490 people and a land area of 729 hectares. It is not known how many of the people were small-scale miners but most were certainly into mining-related activities. Many of the miners have organized themselves into associations but there were also miners who operated independently.

The mining operations in Diwalwal started in 1983 when near-surface gold deposits were discovered by a group of miners. Mining reached a peak in 1985 and subsequently declined but remained substantial up to the present. During its height, the population was reported to have reached about 50,000 people (ECS, MTD 1986).

When it started, mining in Diwalwal was truly small-scale involving narrow and shallow tunnels and manual and artisanal methods. Gold processing was likewise small-scale employing the amalgamation method. At present, however, mining operations have become much more sophisticated. Several operations dig bigger, deeper and well-developed tunnels and use heavy machinery and explosives for ore extraction and mine cars and related equipment for ore transport. They also employ engineers and other technical personnel not seen in any small-scale mining areas elsewhere. Other than amalgamation, some

Figure 5. Map of Compostela Valley provinces showing the municipality of Monkayo and the barangay of Mt. Diwata

Source: Monkayo, Compostela Valley Province Municipal Hall files (1998) processing operations in Diwalwal, particularly the bigger ones, use the CIP method. In 1998, there were 57 CIP plants and about 220 rod mill and ball mill operators.

Diwalwal is highly environmentally sensitive because of its location. The barangay is located at the upper part of the Mamunga River Watershed. The creeks around Diwalwal flow into the Mamunga and Navoc Rivers that, in turn, drain into the Agusan River which is about 24 kilometers away from the mining site. Hence, the impact of mercury pollution due to mining in Diwalwal extends far beyond the site. The provinces of Agusan del Sur and Agusan del Norte that are crossed by the Agusan River and Butuan City, where the mouth of the river is, are also affected. In addition to the research literature cited earlier, the mercury pollution caused by small-scale mining in Diwalwal has been widely reported in the media (Table 8).

Panique and Tugos

Profiles

Figure 6 shows the map of the Philippines highlighting the province of Masbate and the map of the province indicating the municipality of Aroroy and the barangay of Panique.

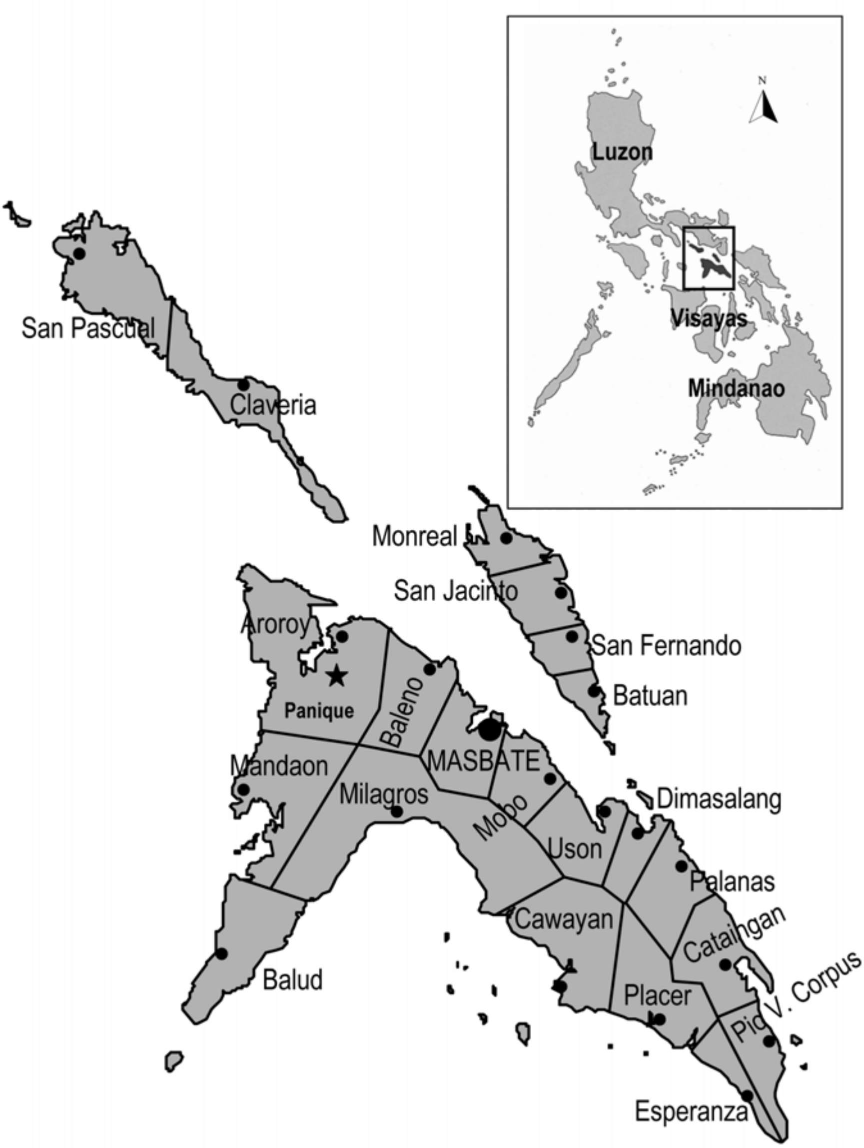
Panique has a land area of 10 hectares. In 1998, it had a population of 5,775 people. The major sources of livelihood of the people were small-scale gold mining, farming, fishing, and vending with the first being the most widely practiced. Based on barangay files, there are presently 825 households in the barangay. Key informants estimated that each household has an average of two members who are miners. This means then that the total number of miners is 1,650. There are about 160 ball mills and 4 CIP operations. For a long time, many small-scale miners have been operating in areas within the mining claim of a large-scale mining firm, the Atlas Mining Company. This firm is now taken over by the Base Metal Mineral Resources Corporation.

Figure 7 provides the map of the Philippines showing the province of Camarines Norte and the map of the province showing the municipality of Paracale and the barangay of Tugos. Tugos has a land area of 9 square kilometers. In 1997, the barangay had a population of 3,625 people. Like in Panique, mining is a major source of livelihood of the

Table 8. Selected newspaper reports on mercury pollution in Diwalwal, Monkayo, Compostela Province, 1997-2000

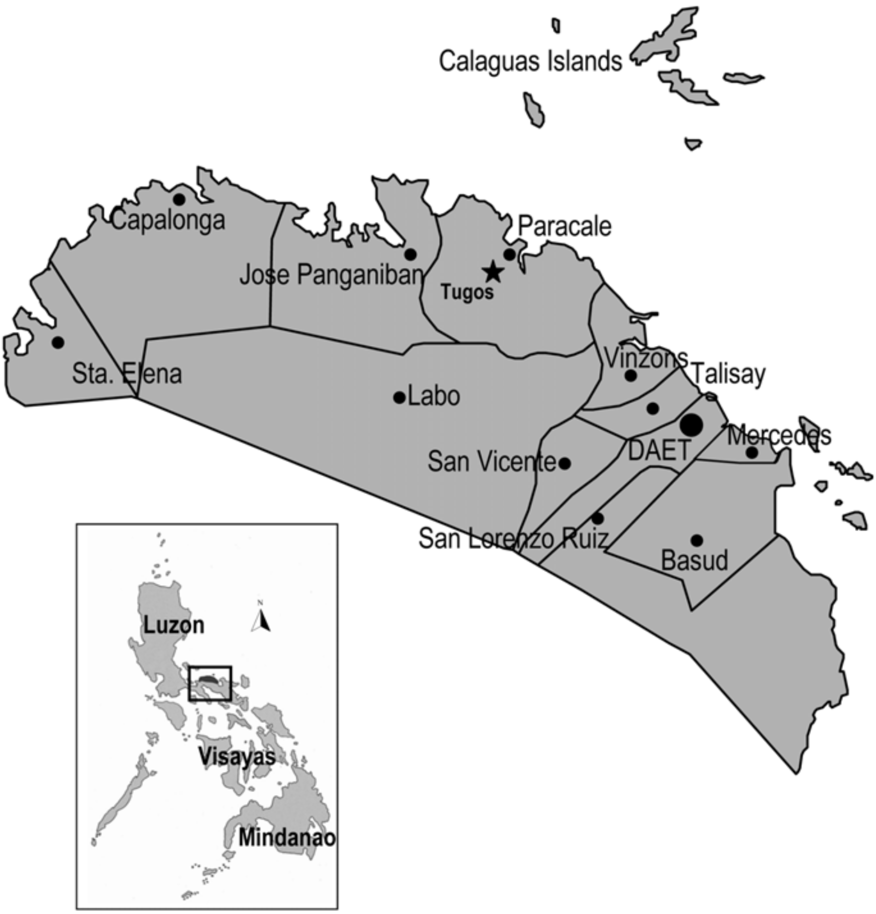
Newspaper	Title/Content	Date
Manila Bulletin	Solon wants Diwalwal mining probed - Environmental problems arising from illegal mining in Diwalwal had reached alarming proportions. Cyanide, mercury and other mine tailings had turned Naboc River in Monkayo into a milky dead body of water.	Jan. 30, 2000
Manila Standard	Kids exposed to mercury poisoning - Children and farmers living near Diwalwal are excessively exposed to mercury poisoning in the illegal gold mines of the mountain. So are lowlanders and their vegetable farms downstream of Monkayo Diwalwal in Davao del Norte.	February 23, 1998
Manila Bulletin	House committee rejects move to lift suspension of mine permits - About 20 million tons of tailings heavily contaminated by mercury around Diwalwal are now polluting the streams, rivers and bays of East Mindanao.	October 3, 1997
The Philippine Star	Diwalwal kids, workers have high mercury, cyanide levels in blood, urine- DOH study - The Department of Health has reported that school-children and workers exposed to mining operations in Diwalwal were detected to have high levels of mercury and cyanide in their blood and urine.	July 9, 1997
The Philippine Journal	DENR monitors four Southern provinces for mercury pollution - DENR is closely monitoring the provinces of Zamboanga del Norte, Cagayan de Oro, Davao del Norte, and Negros regarding the extent of mercury pollution in their particular waterways. The massive use of mercury by small-miners in the Diwalwal gold rush area resulted in mercury contaminaton of rivers, streams and bays and poisoning of residents.	June 28, 1997
Manila Times	Rivers near mining sites have high mercury levels - A number of rivers in Mindanao near gold mine areas are contaminated with mercury due to uncontrolled and improper use of the chemical in mining activities. The British Geological Survey warned that the river below the Diwalwal gold rush area has become a potential health risk due to high levels of mercury caused by the dumping of mine tailings or wastes.	April 21, 1997

Figure 6. Map of Masbate province showing the municipality of Aroroy and the barangay of Panique



Source: Provincial Planning Development Office, Masbate, Masbate (1996)

Figure 7. Map of Camarines Norte province showing the municipality of Paracale and the barangay of Tugos



Source: Provincial Planning Development Office, Daet, Camarines Norte (1999) people in Tugos. Based on barangay files, there are presently about 100 small-scale gold mining tunnels in the area although only 35 are operating. Each tunnel operation is estimated to employ about 11 to 20 miners. Thus, there are 385 to 700 miners in Tugos at present. There are approximately 35 ball mill operators and 10 CIP operators but only half of the CIP plants were reported operating. Part of the small-scale mining operations in Tugos falls within the mining claim of a large-scale mining firm, the United Paragon Mining Corporation.

Case Study Methods

There are no secondary data and past studies done on mercury pollution in the two case study sites so primary data collection was necessary. A brief survey was conducted between April and June 1999 to gather relevant data and information that can help confirm the general occurrence of mercury pollution in small-scale mining areas. Due to time and resource constraints, the survey was conducted through one-time interviews with respondents. The data and information gathered were verified with local government and private key informants.

The respondents of the survey were small-scale miners in general, small-scale miners who were also doing amalgamation and operators of ball mills employing amalgamation. The respondents were selected on a random basis and the total number covered was constrained by available time and resources. Although the survey had fewer respondents than originally hoped for, this was not considered a major problem since mining and processing activities in the two sites were homogeneously small-scale.

The survey gathered demographic, environmental, institutional and financial data and information that were related to mercury pollution. In particular, data on the incidence of mercury pollution were based on perceptions of respondents and were gathered in lieu of physical data that were unavailable from any secondary source or can be gathered only at cost beyond the means of the study.

Demographic Characteristics of Small-Scale Miners

A total of 95 small-scale miners were covered by the survey, 45 in Panique and 50 in Tugos. A substantial number of the miners were married and residing in the mining area with their families (Table 9).

Table 9. Demographic information from small-scale miners in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Civil Status				Are you living alone or with your family in mining area?					Are you also involved in processing activities?			
	Single	Married	No response	Total respondents	Living alone	Living with family	Not living in site	No response	Total respondents	Yes	No	No response	Total respondents
Panique													
Frequency	11	34	0	45	20	21	4	0	45	32	13	0	45
Percentage	24.44	75.56	0.00	100.00	44.44	46.67	8.89	0.00	100.00	71.11	28.89	0.00	100.00
Tugos													
Frequency	10	40	0	50	17	19	14	0	50	50	0	0	50
Percentage	20.00	80.00	0.00	100.00	34.00	38.00	28.00	0.00	100.00	100.00	0.00	0.00	100.00
Total													
Frequency	21	74	0	95	37	40	18	0	95	82	13	0	95
Percentage	22.11	77.89	0.00	100.00	38.95	42.11	18.95	0.00	100.00	86.32	13.68	0.00	100.00

Table 9. Continued...

Survey Area	Are your family members also involved in mining-related activities?				Highest Educational Attainment					Are you a member of a cooperative?			
	Yes	No	No response	Total respondents	Elementary	High School	College	No response	Total respondents	Yes	No	No response	Total
Panique													
Frequency	13	32	0	45	28	14	3	0	45	0	45	0	45
Percentage	28.89	71.11	0.00	100.00	62.22	31.11	6.67	0.00	100.00	0.00	100.00	0.00	100.00
Tugos													
Frequency	38	12	0	50	31	17	1	1	50	0	50	0	50
Percentage	76.00	24.00	0.00	100.00	62.00	34.00	2.00	2.00	100.00	0.00	100.00	0.00	100.00
Total													
Frequency	51	44	0	95	59	31	4	1	95	0	95	0	95
Percentage	53.68	46.32	0.00	100.00	62.11	32.63	4.21	1.05	100.00	0.00	100.00	0.00	100.00

Most were involved in processing activities and many had family-members who were involved in mining-related activities. Practically all attained at least an elementary education. All were not members of cooperatives.

The presence of small-scale miners and their families in the mining area and their involvement in processing imply that a larger number of people, not just the miners, were potentially exposed to mercury pollution. Since miners in general had at least an elementary school education, they were literate and could be trained for the control and prevention of mercury pollution. Their non-membership in cooperatives suggests that small-scale mining was a fairly individual activity where organized efforts to address mercury pollution were likely limited.

Environmental Information from Small-Scale Miners

A majority of the miners have heard of people getting sick due to mercury exposure in their area and some said that they themselves were exposed to mercury during the course of their mining activity (Table 10). A substantial number of miners in Tugos mentioned that their mining area is close to a water body. Of these miners, most claimed that significant siltation, sedimentation and loss of fishery resources have occurred in the water body since mining activities began.

The above data appears to validate the incidence of mercury pollution in small-scale mining areas. They also suggest that this condition has caused health-related problems among miners and other people as well as significant siltation and sedimentation of water bodies and loss of fishery resources.

Institutional Information from Small-Scale Miners

Most of the miners cited that LGUs were monitoring small-scale mining in their area but a good number said the opposite (Table 11). Key informants reported that serious monitoring by LGUs was not done for mercury pollution. Most of the miners mentioned that national government agencies have not been involved in the small-scale mining activities in their area. A majority of miners in Tugos reported that there were nongovernment organizations (NGOs) present in their locality while practically all the miners in Panique said that there were no NGOs in their site.

Table 10. Environmental information from small-scale miners in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Have you heard of people getting sick due to mercury exposure in your area?				Have you been exposed to mercury during the course of your mining activity?				Is your mining area close to a water body?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents
Panique												
Frequency	27	16	2	45	7	30	8	45	4	41	0	45
Percentage	60.00	35.56	4.44	100.00	15.56	66.67	17.78	100.00	8.89	91.11	0.00	100.00
Tugos												
Frequency	22	28	0	50	12	38	0	50	30	20	0	50
Percentage	44.00	56.00	0.00	100.00	24.00	76.00	0.00	100.00	60.00	40.00	0.00	100.00
Total												
Frequency	49	44	2	95	19	68	8	95	34	61	0	95
Percentage	51.58	46.32	2.11	100.00	20.00	71.58	8.42	100.00	35.79	64.21	0.00	100.00

Table 10. Continued...

Survey Area	Have you noticed significant siltation and sedimentation in the water body since mining started?				Have you noticed significant fishery loss in the water body since mining started?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents
Panique								
Frequency	3	1	0	4	3	1	0	4
Percentage	75.00	25.00	0.00	100.00	75.00	25.00	0.00	100.00
Tugos								
Frequency	23	7	0	30	18	12	0	30
Percentage	76.67	23.33	0.00	100.00	60.00	40.00	0.00	100.00
Total								
Frequency	26	8	0	34	21	13	0	34
Percentage	76.47	23.53	0.00	100.00	61.76	38.24	0.00	100.00

Table 11. Institutional information from small-scale miners in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Are Local Government Units monitoring small-scale mining activities in your area?				Is the National Government involved in small-scale mining related activities in your area?				Are there Non-Government Organizations in your area?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents
Panique												
Frequency	34	8	3	45	1	43	1	45	1	43	1	45
Percentage	75.56	17.78	6.67	100.00	2.22	95.56	2.22	100.00	2.22	95.56	2.22	100.00
Tugos												
Frequency	36	13	1	50	9	40	1	50	33	16	1	50
Percentage	72.00	26.00	2.00	100.00	18.00	80.00	2.00	100.00	66.00	32.00	2.00	100.00
Total												
Frequency	70	21	4	95	10	83	2	95	34	59	2	95
Percentage	73.68	22.11	4.21	100.00	10.53	87.37	2.11	100.00	35.79	62.11	2.11	100.00

The above data suggest that, in general, there is little monitoring and enforcement done by both the local and national governments in small-scale mining areas. This neglect must have exacerbated the problem of mercury pollution in these areas. The presence of NGOs in one site points to the potential of this group as active partners in the effort to control mercury pollution. This, however, is presently limited since NGOs are not common in mining sites.

Financial Information from Small-Scale Miners

There were 74 small-scale miners who were also doing amalgamation processing covered by the survey, 34 in Panique and 40 in Tugos. The average ore production of the miners varied significantly between the two case study sites (Table 12). More miners processed their ore in other ball mills but a significant number did so in mills owned by the owner of the tunnel they gathered the ore from. Detailed production cost and returns data were difficult to generate from the miners but their estimated average annual gross and net incomes were positive but low. Key informants indicated that although the average incomes of small-scale miners were low, they were generally sufficient for the standard of living in their areas.

Since the incomes of small-scale miners were low, they may also have low willingness to pay for any environmental damage that mercury pollution emanating from their activities causes. On the other hand, since their incomes are positive, they may be able to pay for some form of expenditures for their personal protection from mercury pollution, particularly if this requires only small deductions from their earning.

Environmental Information from Ball Mill Operators

There were 45 ball mill operators covered by the survey, 25 from Panique and 20 from Tugos. The ball mill operators did not require the small-scale miners and workers doing amalgamation to use gloves as protective equipment in the handling of mercury and other chemicals during processing (Table 13). All the operators mentioned that they had tailings ponds to contain the wastes they produced. However, key informants said that the ponds were generally inadequate to handle the volume of wastes. This was evidenced by the fact that of those operators who said that their sites were close to a water body, the majority

Table 12. Financial information from small-scale miners also doing amalgamation processing in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Average ore production per month				Where is the ore processed?				Average annual gross income				Average annual net income			
	In Kgs.	Number responded	No response	Total respondents	Tunnel owners' ball mill	Other ball mill	No response	Total respondents	In Pesos	Number responded	No response	Total respondents	In Pesos	Number responded	No response	Total respondents
Panique	742.2								29,568				22,648			
Frequency		34	0	34	16	16	2	34		34	0	34		34	0	34
Percentage		100.00	0.00	100.00	47.06	47.06	5.88	100.00		100.00	0.00	100.00		100.00	0.00	100.00
Tugos	349.3								30,664				24,929			
Frequency		40	0	40	14	26	0	40		40	0	40		40	0	40
Percentage		100.00	0.00	100.00	35.00	65.00	0.00	100.00		100.00	0.00	100.00		100.00	0.00	100.00
Total																
Frequency		74	0	74	30	42	2	74		74	0	74		74	0	74
Percentage		100.00	0.00	100.00	40.54	56.76	2.70	100.00		100.00	0.00	100.00		100.00	0.00	100.00
Average	545.8								30,116				23,789			

Table 13. Environmental information from small-scale ball mill operators in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Do you require gloves as protective equipment in the handling of mercury and other chemicals?				Is there a tailings pond in the processing area?				Is your processing area close to a water body?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents
Panique												
Frequency	0	25	0	25	25	0	0	25	18	7	0	25
Percentage	0.00	100.00	0.00	100.00	100.00	0.00	0.00	100.00	72.00	28.00	0.00	100.00
Tugos												
Frequency	1	19	0	20	20	0	0	20	14	6	0	20
Percentage	5.00	95.00	0.00	100.00	100.00	0.00	0.00	100.00	70.00	30.00	0.00	100.00
Total												
Frequency	1	44	0	45	45	0	0	45	32	13	0	45
Percentage	2.22	97.78	0.00	100.00	100.00	0.00	0.00	100.00	71.11	28.89	0.00	100.00

Table 13. Continued...

Survey Area	Have you noticed significant siltation and sedimentation in water body since your processing activities started?				Have you noticed significant fishery loss in the water body since your processing activities started?				Is blowtorching of the amalgam done indoors or outdoors?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Indoor	Outdoor	No response	Total respondents
Panique												
Frequency	11	7	0	18	10	8	0	18	7	18	0	25
Percentage	61.11	38.89	0.00	100.00	55.56	44.44	0.00	100.00	28.00	72.00	0.00	100.00
Tugos												
Frequency	12	2	0	14	13	1	0	14	8	12	0	20
Percentage	85.71	14.29	0.00	100.00	92.86	7.14	0.00	100.00	40.00	60.00	0.00	100.00
Total												
Frequency	23	9	0	32	23	9	0	32	15	30	0	45
Percentage	71.88	28.13	0.00	100.00	71.88	28.13	0.00	100.00	33.33	66.67	0.00	100.00

Table 13. Continued...

Survey Area	Are retorts used in blowtorching of the amalgam?				Have you heard of people getting sick due to mercury exposure in your area?				Have you been exposed to mercury during the course of your mining activity?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents
Panique												
Frequency	0	25	0	25	22	3	0	25	8	17	0	25
Percentage	0.00	100.00	0.00	100.00	88.00	12.00	0.00	100.00	32.00	68.00	0.00	100.00
Tugos												
Frequency	0	20	0	20	12	8	0	20	14	6	0	20
Percentage	0.00	100.00	0.00	100.00	60.00	40.00	0.00	100.00	70.00	30.00	0.00	100.00
Total												
Frequency	0	45	0	45	34	11	0	45	22	23	0	45
Percentage	0.00	100.00	0.00	100.00	75.56	24.44	0.00	100.00	48.89	51.11	0.00	100.00

also mentioned that significant siltation, sedimentation and loss of fishery resources have occurred in the water body since their processing activities commenced.

Most ball mill operators reported the blowtorching of amalgam was done outdoors in their operations but a good number also said that this was conducted indoors. All said that mercury retorts were not used in the blowtorching process. Many reported that they have heard of people in their area getting sick due to mercury and some also claimed that they themselves have been exposed to it.

That mercury retorts were not used during blowtorching further points to the gravity of mercury pollution in small-scale mining areas. It is interesting to note that some of the ball mill operators, who may not be as directly involved in processing as the small-scale miners and workers, admit that they themselves were also exposed to mercury pollution.

Financial Information from Ball Mill Operators

The average amount of ore processed by the ball mill operators were not the same in the two sites although the difference does not appear to be significant (Table 14). Detailed data on costs and returns were also difficult to generate from the ball mill operators. On average, operators in one site were found to have higher annual gross and net incomes than in the other. The levels of incomes in both sites appear low for business enterprises but nevertheless positive. Key informants said that these levels were acceptable for a business activity in a rural area.

Since ball mill operators earned low but positive incomes from their operations, like the small-scale miners, they are likely less willing pay for the damages due to mercury pollution they cause, if these are substantial. As in the case of small-scale miners, however, they may be able to pay for relatively minor expenditures for the prevention of mercury pollution.

Table 14. Financial information from ball mill operators in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Average ore processed per month				Average annual gross income				Average annual net income			
	in Kgs.	Number responded	No response	Total respondents	in Pesos	Number responded	No response	Total respondents	in Pesos	Number responded	No response	Total respondents
Panique	509.6				120,230				51,228			
Frequency		25	0	25		25	0	25		25	0	25
Percentage		100.00	0.00	100.00		100.00	0.00	100.00		100.00	0.00	100.00
Tugos	532.0				300,514				71,172			
Frequency		20	0	20		20	0	20		20	0	20
Percentage		100.00	0.00	100.00		100.00	0.00	100.00		100.00	0.00	100.00
Total												
Frequency		45	0	45		45	0	45		45	0	45
Percentage		100.00	0.00	100.00		100.00	0.00	100.00		100.00	0.00	100.00
Average	520.8				210,372				61,200			

ECONOMIC VALUATION OF MERCURY POLLUTION IN SMALL-SCALE MINING

Valuation Methods

There are different potential methods for estimating the economic costs of mercury pollution due to small-scale mining. One is the loss of incomes approach that considers the incomes forgone by the people affected by mercury pollution as a measure of the economic costs of the problem. This method, however, is demanding since it requires a thorough physical accounting of the dose of mercury produced by small-scale mining over time and the exact response to mercury pollution (in terms of morbidity or mortality) of the affect population. It also needs accurate income data from the individuals affected over time to convert the mortality and morbidity cases into economic values.

Another potential valuation approach, which can be used together with the loss of income method, is the productivity change method that estimates the economic value of the lost aquatic resources due to mercury pollution. This method is likewise tedious to apply because data on the physical dose of mercury into the environment and the exact volume of fish killed and rendered inedible as a result of it over time are needed. In addition, historical price data on the fish species in the locality are required to convert the lost fishery output into money values.

The loss of incomes and productivity change methods then are not used in this study. The primary reason is that there are no available epidemiological and fishery productivity studies for small-scale mining already available that can provide accurate dose-response estimates between mercury pollution on one hand and human health or fish productivity on the other hand.

Still another valuation method that can be used to measure the economic costs of mercury pollution due to small-scale mining is the contingent valuation method. Briefly, this approach asks the affected population their willingness to pay for the mitigation of mercury pollution or their willingness to accept the pollution and take either of these as a measure of the economic cost of the problem. The contingent valuation technique has important limitations, however. In particular, it is inaccurate to apply among the poor small-scale miners whose willingness to pay for mercury pollution mitigation or accept mercury pollution as a result is low or even zero.

For practical purposes, this study uses the defensive expenditures approach to measure the economic costs associated to mercury pollution due to small-scale mining. This method directly measures the cost of putting up the necessary facilities and equipment that can prevent mercury pollution from happening (assuming they are available) and takes these as an estimate of the economic costs of the problem. The defensive expenditures approach is limited in that it measures only the cost of future mercury pollution and not past pollution.

The Economic Costs of Mercury Pollution

The wearing of hand gloves as protective equipment by small-scale miners and ball mill or rod mill workers while handling mercury helps reduce the risk of mercury contamination. The cost of hand gloves is an important defensive expenditure item.

Retorts that trap mercury during blowtorching and prevent it from spreading into the air reduces the risk of exposure to mercury among those conducting blowtorching and the people nearby. The cost of mercury retorts is another important defensive expenditure item. An illustration of a mercury retort is provided in Figure 8.

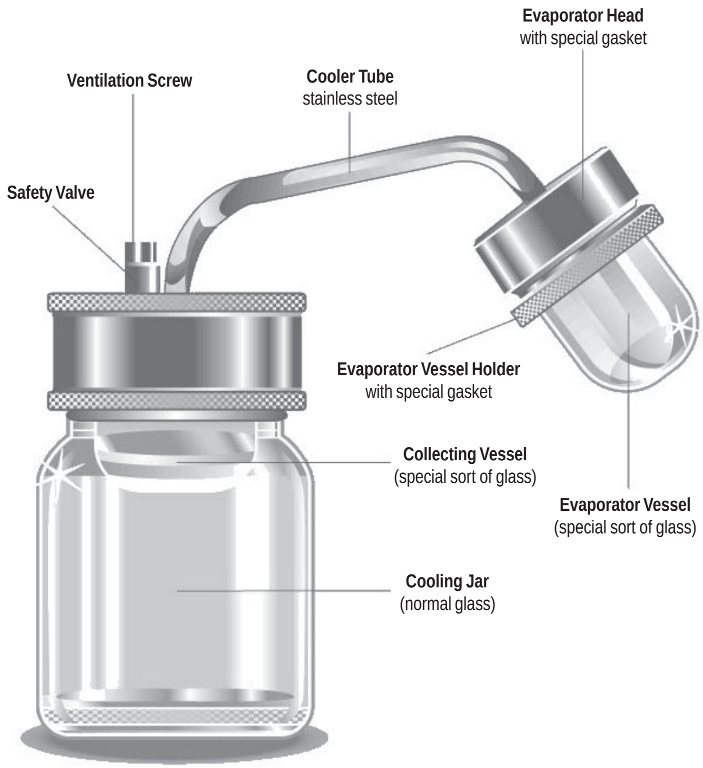
Adequate tailings ponds that effectively prevent the spillage of mercury and other small-scale mining wastes into rivers and waterways also help prevent mercury pollution. The cost of tailings ponds is yet another important defensive expenditure item.

<u>Cost of Hand Gloves</u>

Based on the results of the survey in the two case study sites, an average of 86 percent of small-scale miners were involved in gold processing (Table 9). Assuming this ratio and the estimated 250,000 total small-scale miners in the country holds, there would be about 215,000 of them involved in processing. This total does not include the undetermined number of workers in ball mills and rod mills nationally.

The current price of good quality industrial rubber hand gloves suited for gold processing (which can last at least a year) is P500.00 per pair, at the most, based on market canvass at year 1999 prices. Using this price, the total cost of the gloves for miners involved in amalgam-

Figure 8. Illustration of a Retort



Source: Original Therm Owner's Manual (1998) ation in the entire country is P107.5 million. This figure seems large for mere gloves especially if the workers in the mills are added in the coverage. However, the gloves should be affordable if puchased individually by the miners as their costs form only a small percentage of their net incomes (Table 12). Furthermore, the actual price of the gloves on a per unit of time basis should be significantly lower if they are used carefully to last longer than the assumed economic life of just a single year.

<u>Cost of Mercury Retorts</u>

There are mercury retorts sold in the market and based on market canvass, the current price of the retorts should not be more than $1,000 per unit or P40,000 based on year 1999 exchange rate.

The marginal cost and returns analysis for the use of a retort during its entire economic life is shown in Table 15. The marginal costs of using a retort in gold processing include its purchase price and the cost of repair and maintenance. There is no marginal labor cost in the operation of a retort since it can be done as part of the blowtorching activity. The marginal revenues come from the retrieved mercury and gold with the use of the retort. The ratios used to estimate the retrieved mercury and gold with the use of the retort come from key national and local informants.

Based on 100 percent mercury and gold recovery efficiency rate, the retort will actually gain its user about half a million pesos during its entire economic life. If less than 100 percent efficiency rate is assumed, the retort will still benefit the user generally (Table 16). It is only at an efficiency rate of a very low 8.6 percent that the use of the retort is just economically breakeven. Below this, the use of the retort will cost the user on the net.

Theoretically, if the retorts are efficiently used on a sharing basis, only a few retorts will be needed for all small-scale mining areas in the country. Rough estimates can be done to ascertain the total requirement. From key informants, the mercury to gold ratio in an amalgam is about 3 to 1 (Table 15). Therefore, assuming that the 1992 gold production level of 6,826 kilograms holds, the total amalgam produced is 27,304 kilograms. Since each retort can process 350 kilograms of amalgam in its entire economic life, then the total number needed is 78 pieces. At a

Table 15. Marginal costs and returns of the use of a mercury retort in gold processing, 1999

Item	Quantity	Value / piece	Total value
Marginal costs			
Purchase price of retort [1]	1 piece	P 40,000/piece	P 40,000.00
Repair and maintenance [2]			8,000.00
Total costs			P 48,000.00
Marginal returns			
Retrieved mercury [3]	262,500 grams	P 0.371 per gram	97,387.50
Retrieved gold [4]	1,750 grams	P 260 per gram	455,000.00
Total returns			P 552,387.50
Net income			P 504,387.50

Notes: [1] The retort is depreciated fully at the end of its economic life.

[2] The total repair and maintenance cost during the entire life of the retort is 20% of its purchase price. No additional labor cost in the operation of the retort is assumed.

[3] The economic life of a retort is 500 hours. Per batch of use takes 30 minutes. Therefore, 1,000 batches can be accomodated during its whole economic life. Load per batch is 350 grams of amalgam of which 75% is mercury and 25% is gold. Mercury recovery per batch is 100%, or 262.5 grams. Hence, the total recovered mercury during the whole economic life of the retort is 262,500 grams at 1,000 batches.

[4] If the retort is not used, blowtorching results to the loss of about 2% of the processed gold. The use of the retort will result to 100% gold recovery. It is assumed that the recovered gold per batch is about 25% of the amalgam, or 87.5 grams of 350 grams load per batch. The 2% of this or 1.75 grams, are saved due to the retort. Given 1,000 batches, total gold saved is 1,750 grams.

price of P48,000 including maintenance cost, the total cost of the retorts is P3.7 million.

Since the retorts may actually be less than 100 percent efficient and definitely cannot be fully shared by its users because of the distance between mining sites and the individual processing operations, more retorts will be required overall. Still, even if the cost is magnified 10 times, the total cost at P37 million is still small relative to the potential problems mercury pollution poses. Furthermore, as shown earlier, retorts will likely actually earn under most circumstances and this should add to their attractiveness for small-scale gold processing.

Table 16. Sensitivity analysis of the use of a retort, 1999

	Mercury Retrieval Efficiency					
	100%	75%	50%	25%	8.6%	0%
Marginal costs (Pesos)	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00
Marginal returns (Pesos)						
Retrieved mercury	97,387.50	73,040.63	48,693.75	24,346.88	8,462.54	-
Retrieved gold	455,000.00	341,250.00	227,500.00	113,750.00	39,537.45	-
Net income (Pesos)	504,387.50	366,290.63	228,193.75	90,096.88	0.00	(48,000.00)

Source: Table 12

Key informants in the two case study areas claimed further that mercury retorts can be produced locally at a much reduced price. This should enhance their viability as economic and environmental equipment in the small-scale mining areas. Moreover, even at the relatively high price assumed in the study, the retorts should be affordable to ball mill operators or even to small-scale miners especially if they are purchased and used on a sharing basis (Tables 12 and 14).

Cost of Tailings Ponds

Based on Santelices (1997), the NSCB (1998) made estimates of the volume of small-scale mine tailings produced and the impoundment cost per unit of the tailings for the period 1988-1994. These data are expanded to cover the period up to 1999 by using simple average annual growth rates (Table 17). An additional variable, the total cost of impoundment, was added by multiplying tailings generated by the impoundment cost per unit. For 1999, the total amount of tailings generated by small-scale mining was 9.2 million metric tons while the cost of impoundment per metric ton was P107. The total cost of impoundment nationally was about P986.5 million.

Table 17. Impoundment cost of tailings generated by small-scale gold mining, 1984-1999

Year	Tailings Generated (MT)	Cost of Tailings Impoundment (Pesos/MT)	Total Cost (Pesos)
1999	9,217,056	107.03	986,456,184.90
1998	7,759,118	102.80	797,637,330.40
1997	5,428,921	101.62	551,686,970.81
1996	6,027,490	100.59	606,305,172.55
1995	5,662,566	94.01	532,337,830.76
1994	4,576,235	89.09	407,696,776.15
1993	3,498,975	84.15	294,438,746.25
1992	2,896,727	84.32	244,252,020.64
1991	3,392,945	80.64	273,607,084.80
1990	2,031,526	67.56	137,249,896.56
1989	3,189,369	57.41	183,101,674.29
1988	2,688,909	49.18	132,240,544.62

Source: NSCB (1998).

The cost of impounding the tailings from small-scale mining will be shared by the ball mill operators, CIP operators and the miners all over the country. Since the total tailings from amalgamation operations alone is not known, suffice it to say here that the mill operators should share a substantial part of the cost being the more dominant processors. Assuming, for instance, that ball mill and rod mill operations produce 80 percent of the tailings, then the cost of impoundment to them amounts to P789 million annually.

It has to be ascertained if the cost of impoundment is affordable to the ball mill and rod mill operators. The average volume of wastes produced per month by the mills in the two case study site is not known because the responses of respondents were inconsistent and unreliable. However, the average cost of impoundment of P107 per metric ton is certainly reasonable to the mill operators. In addition, since many of them already have tailings ponds, improvements to make the ponds adequate should cost less on average.

Total Costs of Preventive Equipment and Facility

Table 18 summarizes the total costs of the equipment and facility needed nationally to control the occurrence of future mercury pollution in small-scale mining in the country annually. Hand gloves cost P107.5 million, mercury retorts cost P37 million and tailings ponds cost P789 million under certain assumptions. The total cost is P933.5 million or less than a billion pesos.

OTHER PROBLEMS IN SMALL SCALE GOLD MINING

Pollution due to Aside from mercury pollution, small-scale mining is beset with other problems that are also important and needing serious attention. These are enumerated and discussed in brief below.

Other Environmental Problems

Cyanide Pollution

Pollution due to toxic and hazardous substances other than mercury that are used in small-scale mining can also endanger human health. The highly poisonous sodium cyanide used in CIP processing, in particular, could easily kill people and fish when discharged in rivers and

Table 18. Summary of estimated defensive expenditures for mercury pollution prevention in small-scale mining areas in the Philippines

Item	Total Costs (Million Pesos)
Hand Gloves	107.5
Mercury Retorts	37
Tailings Ponds	789
Total	P 933.5

Notes: The cost of the retort at P 3.7 million is magnified 10 times to account for inefficiency and non-sharing. The amalgamation processors are assumed to be responsible of 80% of the wastes produced by small-scale mining.

waterways. Despite its dangers, cyanide pollution from CIP processing has not been investigated at all in any literature. A probable reason is that, unlike mercury, cyanide is biodegradable and eventually decomposes into carbon dioxide and ammonia (Yannopoulos 1991) making it potentially less harmful over time.

Deforestation

Deforestation is a natural consequence of small-scale mining since many sites are located in forested uplands. The influx of miners and their families into mining areas results to the clearing of forests for habitation space and other human activities that causes deforestation. No study investigated in detail the impact of small-scale mining on deforestation. One likely reason is that areas covered by small-scale mining are actually very small when compared to those used for other economic activities like forestry and logging (Veiga 1997b).

Soil Erosion

Soil erosion is another natural consequence of small-scale mining because of the mountainous and sloping topography of many mining sites. Miners level sloping land and scrape topsoil to make surface foundations stable for houses and other structures. They develop pathways and roads across highly sloping and erosive areas and cover fertile soil with waste materials dug out of underground tunnels. There are also no studies that probed in detail the soil erosion effects of small-scale mining although this environmental impact is potentially large.

Biodiversity Loss

The loss of biodiversity due to small-scale mining is a direct aftermath of deforestation and water pollution. Trees are cut leading to receding jungles that are natural habitats of terrestrial flora and fauna. Water pollution damages the rivers and waterways that are homes of aquatic plants and animals. As in the case of deforestation and soil erosion, there are no studies that investigated this issue.

Siltation and Sedimentation of Downstream Water Bodies

Siltation and sedimentation of downstream waterways occur when mine tailings and eroded soil find their way into water bodies. They decrease the viability of affected waterways as fishing grounds, recreation sites and port areas. They also contribute to flooding and hamper the efficient functioning of dams and irrigation networks. Like the other environmental problems, siltation and sedimentation due to small-scale mining have received scant research attention.

Legal and Institutional Problems

Mining Rights Conflicts between Small-Scale Miners and Large-Scale Mining Firms

Many small-scale mining areas, including the two case study areas, are situated within the mining claims of large-scale companies. This situation has created conflicts between the large-scale miners on one side and the small-scale miners on the other side and prevented the smooth operations of the mining industry in general.

Presence of Medium-Scale Mining Operations in Small-Scale Mining Sites

Although small-scale mining is generally homogeneous in the two case study areas, there is a dominant presence of medium-scale mining operations in some other sites, particularly Diwalwal. This situation has reduced the small-scale miners into mere laborers or poor competitors of the larger mining operations. Furthermore, the medium-scale mining firms in the area have been competing for domination resulting in the significant loss of lives and deterioration of peace and order (Table 19).

Table 19. Selected newspaper reports on peace and order problems in Diwalwal, Monkayo, Compostela Province, 1999-2000

Newpaper	Title/Content	Date
Philippine Daily Inquirer	4 killed in mining explosion - Four miners were killed and 14 others were injured after an explosion caused fire and poisonous fumes to engulf several tunnels in the Diwalwal gold rush area in Monkayo, Compostela Valley. It was reported that workers from Helica Mining Corp. triggered the explosion by setting a dynamite attached to a liquified petroleum gas (LPG) tank.	March 1, 2000
Philippine Daily Inquirer	Clashes erupt in Diwalwal; 1 dead, 11 hurt - One person was killed while many others hurt as clashes between JB Management Mining Corp. (JBMMC) and its rival, Helica Gold Mining Corp. (HGMC) continued inside the tunnels in the Diwalwal gold rush area in Monkayo, Compostela Valley. Both firms are fighting over control of strategic mining tunnels.	January 14, 2000
The Mindanao Daily Mirror	3 women killed in Diwalwal ambush - A band of unidentified armed men ambushed a convoy of vehicles belonging to JB Management Mining Corp., killing three women, two of them hitchhikers and wounding three persons, including a child passenger.	April 8, 1999
Philippine Daily Inquirer	3 miners die in ambush - Three miners were killed in an ambush in what police said could be related to the raging dispute at the gold-rush area at Diwalwal in Monkayo, Compostela Valley.	March 21, 1999
The Mindanao Daily Mirror	Miners aboard truck ambushed; 3 killed - Three miners aboard a dump truck were killed after they were ambushed by heavily-armed men in sitio Macopa, Upper Ulip, Monkayo, Compostela Valley Province. Reports said that fatalities could have been victims of a "war" among miners.	March 20, 1999

Social Problems

Worsening Social Instability in Small-Scale Mining Areas

Many small-scale miners are migrants in the areas where they mine (Table 20). Hence, they find it difficult to adapt socially with the local population. To some extent, vices like alcoholism and gambling also exist in these areas that add to the conflict (Table 20).

Table 20. Other demographic information from small-scale miners in Panique, Aroroy, Masbate and Tugos, Paracale, Camarines Norte, 1999

Survey Area	Are you a migrant to the area?				Are alcoholism and gambling common activities in your mining area?				Are public health clinics and hospitals accessible in your mining area?				Are there good roads which link your mining area to the community center?			
	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents	Yes	No	No response	Total respondents
Panique																
Frequency	21	24	0	45	9	33	3	45	8	36	1	45	1	44	0	45
Percentage	46.67	53.33	0.00	100.00	20.00	73.33	6.67	100.00	17.78	80.00	2.22	100.00	2.22	97.78	0.00	100.00
Tugos																
Frequency	19	31	0	50	10	40	0	50	41	9	0	50	31	19	0	50
Percentage	38.00	62.00	0.00	100.00	20.00	80.00	0.00	100.00	82.00	18.00	0.00	100.00	62.00	38.00	0.00	100.00
Total																
Frequency	40	55	0	95	19	73	3	95	49	45	1	95	32	63	0	95
Percentage	42.11	57.89	0.00	100.00	20.00	76.84	3.16	100.00	51.58	47.37	1.05	100.00	33.68	66.32	0.00	100.00

Table 20. Continued...

Survey Area	Gold buyers					Are you also engaged in farming or in other economic activities?				Average length of time mining			
	Tunnel owner	Ball mill owner	Other gold buyers	No response	Total respondents	Yes	No	No response	Total respondents	in years	Number responded	No response	Total respondents
Panique										7.5			
Frequency	14	14	6	0	34	6	39	0	45		44	1	45
Percentage	41.18	41.18	17.65	0.00	100.00	13.33	86.67	0.00	100.00		97.78	2.22	100.00
Tugos										11.3			
Frequency	4	22	14	0	40	9	41	0	50		50	0	50
Percentage	10.00	55.00	35.00	0.00	100.00	18.00	82.00	0.00	100.00		100.00	0.00	100.00
Total													
Frequency	18	36	20	0	74	15	80	0	95		94	1	95
Percentage	24.32	48.65	27.03	0.00	100.00	15.79	84.21	0.00	100.00		98.95	1.05	100.00
Average										9.4			

Limited Basic Services in Small-Scale Mining Areas

The supply of basic services such as those relating to health and transportation and others has been limited in small-scale mining communities (Table 20). This has greatly exacerbated the poor conditions and social problems within these areas.

Exploitation of Women and Children in Small-Scale Mining

Women and children are engaged in the gathering of ores inside tunnels and even in processing which are activities suited only for grown-up men. Although small-scale miners deny this, key informants and ocular inspection in the two case study areas confirmed this problem.

Economic Problems

Low Price for Gold Received by Small-Scale Miners

Small-scale miners sell their gold to the tunnel owners, processors or to other traders instead of directly to the Central Bank or its representatives (Table 20). Key informants reported that underpricing of gold often occurs in these marketing channels and this contributes to the poor economic conditions the miners are in.

Loss of Gold by the Country Due to Illegal Gold Trading

Because small-scale miners sell their gold not to the Central Bank but to various buyers, the national government loses great amounts of gold to the detriment of the entire economy.

Lack of Formal Sources of Credit for Small-Scale Miners

There is lack of formal sources of credit for small-scale miners in times of need or for starting an alternative occupation. This forces them to borrow from the tunnel owners, processors, traders and unscrupulous money lenders who exploit them by charging higher interest rates or buying their gold at low prices.

Lack of Alternative or Supplemental Employment Opportunities for Small-Scale Miners

Small-scale mining is the only employment opportunity for many miners. Few have an alternative occupation like farming (Table 20). Also, many miners have been in mining for an average of 10 long years, which further confirms their lack of alternative employment (Table 20).

Technology-related Problems

Inefficient Technologies Used in Small-Scale Mining

The technology used in ore extraction and gold processing results to poor ore output and gold recovery in small-scale mining. The poor ore and gold output performance has been confirmed by national and local key informants.

Unsafe Technologies Used in Small-Scale Mining

The unsafe techniques and procedures used in the mining of ore, such as poor timbering support, poor ventilation, and other practices have resulted to cave-ins and other accidents that disabled or took away the lives of miners. These have been confirmed by the numerous reported accidents that occurred in Diwalwal over time (Table 21).

Table 21. Mining accidents in Diwalwal, Monkayo, Compostela Province, 1998-1999

Newpaper	Title/Content	Date
The Philippine Star	Diwalwal cave-in kills 12 - At least 12 miners searching for gold were believed to have been buried alive inside tunnels that caved in over the weekend in Diwalwal, Compostela Valley.	September 21, 1999
Manila Bulletin	Rescue on for trapped miners - Police and volunteers intensified operations to rescue 10 miners trapped in a tunnel in a Southern Philippine mountain for five days following a landslide. One miner has been confirmed dead, while three were rescued from the mining site in Diwalwal in Monkayo town.	November 30, 1998
Philippine Daily Inquirer	Diwalwal mining now very risky, says DENR exec. - The MGB warned mining is highly dangerous and risky in Diwalwal with the onset of rains and the La Nina phenomenon. Cave-ins and landslides are highly probable when heavy rains loosen and weaken soil inside tunnels.	June 5, 1998
The Philippine Star	DENR team probes claims 80 dies in Diwalwal cave-in - An eiqht-member team from the DENR started an investigation into claims that 80 gold miners were killed in a tunnel collapse - not six as the government maintains.	January 7, 1998
Philippine Daily Inquirer	Rescue miners in Diwata cave, Ramos orders -President Ramos has ordered to launch rescue operations to save gold miners trapped in a tunnel which collapsed in Diwalwal, Davao Del Norte. The cave-in was believed to have been caused by heavy rains.	January 1, 1998

RECOMMENDATIONS

The paper puts forward the following recommendations for addressing the various problems in small-scale mining.

Mercury Pollution

A review will show that the existing laws and regulations related to mercury pollution in small-scale gold mining are fairly adequate but monitoring and enforcement is weak. To improve on monitoring and enforcement, the following actions are suggested:

• *Licensing by the LGUs of all small-scale gold mining and processing operations within their jurisdiction and imposition of membership in a cooperative as a licensing requirement*. Licensing will give legal status to the miners and processors while organizing them into cooperatives will help facilitate common efforts for improved environmental management. An added advantage of cooperatives is that they promote better marketing of the gold produced by the miners.

• *Earmarking of the licensing proceeds for the establishment and operation of a small-scale mining monitoring and enforcement unit within the management framework of LGUs*. Together with other relevant local and national law enforcement units, this office will have as major function the apprehending of violators and imposition of appropriate penalties on them.

• *Development of an effective internal system within cooperatives that will force the proper use of hand gloves, mercury retorts and tailings ponds in small-scale mining.* Miner cooperatives should impose a fee on their members for the purchase and distribution of hand gloves and other protective equipment. Processor cooperatives should impose the use of mercury retorts and appropriate tailings ponds.

• *Active involvement of NGOs and other responsible members of the local population in monitoring and enforcement by selectively deputizing them.* With these additional watchdogs, the cost of environmental management to the LGUs will be lowered while increasing coverage at the same time .

• *Strengthening of the Small-Scale Mining Section of the Environment and Safety Division of the MGB*. This section has staff at both the national and regional offices of the bureau. Reinforcing it is essential because it is the national government office that oversees small-scale mining and coordinates with LGUs for such purpose.

• *Concerted effort by the national government, LGUs and NGOs to conduct education and awareness campaigns on mercury pollution*. Miners in general are not fully knowledgeable of the health risks associated to mercury pollution. Heightened education and awareness should make them more voluntarily compliant to governance.

• *Involvement of international organizations in the fight against mercury pollution particularly in the promotion of technologies that can prevent or minimize it.* An example of this is the project of the United Nations Industrial Development Organization (UNIDO) that promotes the use of mercury retorts among miners in Diwalwal.

• *Serious consideration of the promotion of the CIP method of processing for small-scale mining*. This method may be less dangerous to human health but this is not widely used due to high investment requirement. With cooperatives, the pooling of funds will allow the operation of CIP plants communally.

• The above actions, however, will address only future mercury pollution and not pollution already in place. For existing mercury pollution, it is financially very costly for the government to dredge and clean-up entire rivers and waterways affected by the problem*. A practical approach is to identify populated sites with high level of mercury contamination. Then, selective clean-up can be done in these sites*.

Other Environmental Problems

The national government should undertake detailed studies on cyanide pollution, deforestation, soil erosion, biodiversity loss and siltation and sedimentation in small-scale mining areas. Understanding these problems will go a long way toward finding their appropriate solutions. For the time being, the government must do better in monitoring and enforcing pertinent laws so that the problems are minimized.

Legal and Institutional Problems

The government should prioritize the early settlement of conflicting claims between small-scale miners and large-scale miners. One way of conducting this is to create dialogues between the two parties with the government as arbiter to find an amicable solution. Key informants from the large-scale firms in the two case study areas explained that generally they are actually open to a negotiated settlement that can buy peace, goodwill and cooperation within their claims.

The presence of medium-scale operators in small-scale mining sites should be seriously studied by the government. As a general rule, the government should adhere to the strict definition of small-scale mining in the granting of licenses to operate. The concept of fairness and level playing field must be followed. Otherwise, the goal of true small-scale mining development is not served.

The case of Diwalwal, however, must be afforded special treatment in the granting of licenses. It may be impractical or even politically incorrect to remove the numerous medium-scale firms in the area that have been operating there for a long time. A serious study on the various problems in Diwalwal and the appropriate management system to be applied there must be conducted immediately. At present, a step in the right direction is to license operations in the area so the government will generate revenues and improve environmental management there.

Social Problems

The social instability in small-scale mining is inherent in places where many of the population are poor and migrants. Improving the economic status of the people can help a lot to decrease the instability. This could happen when small-scale mining becomes a fully licensed activity and accepted as part of the economic mainstream. The provision of better basic social services will also help alleviate the deprived economic conditions and ease a lot of the social tensions.

The exploitation of women and children is not confined to small-scale mining since it is prevalent, especially in the underground economy. The Department of Social Welfare and Development (DSWD) should take a closer look at this problem and devise ways to minimize it. Again, improving the economic lot of the miners will help curve the exploitation of women and children. The conduct of effective programs which can provide guidance and counseling to mining families will also promote compliance by the miners to the laws against exploitation.

Economic Problems

The problem of low price received for the gold by the small-scale miners will be addressed to a large extent when they are organized into cooperatives. As a group, they can negotiate better in the market or pay for the transportation cost to sell gold in bulk to the Central Bank. The Central bank should consider putting up buying stations in the more important mining sites. This will not only help the miners economically but also lower significantly the amount of gold lost to the black market.

Since there are credit and alternative livelihood programs for other disadvantaged economic groups like farmers and fishermen, one should also be contemplated for small-scale miners. There is little question that they are among the poorest of the poor who direly need assistance. Such programs will be politically expedient given the large number of miners and their dependents nationally.

Technology-Related Problems

The problems of inefficient and unsafe technologies are part and parcel of small-scale mining as long as the miners remain poor. Economic conditions force them to use said technologies since they cannot afford to employ more sophisticated and costly ones. Several of the steps already suggested above should help change the economic plight of farmers and allow them to use better technologies. The availability of credit, for one, will provide them some leeway in considering and applying better and safer technologies. Subsidized training will also open their eyes to the economic and environmental advantages that advance technologies bring.

CONCLUSIONS

To recapitulate, this study probed into mercury pollution in small-scale mining in the Philippines. Despite the seriousness of the problem, small-scale mining is an occupation of last resort to many poor people who are into it because of economic necessity. Worsening poverty ensures that the activity is here to stay.

The problem of mercury pollution demands that stronger monitoring and enforcement efforts be exerted by the government at both the national and local levels. Legalizing the activity by licensing miners will help improve environmental management. Serious enforcement of the laws and regulations regarding the use of protective equipment like hand gloves, mercury retorts and tailings ponds will also help.

The future development of the small-scale mining industry also hinges on the finding on effective solutions to the various other problems the industry is facing. With the cooperation of the private sector and the citizenry in the mining communities, a more proactive government that mediates conflicts, provides tangible assistance and exerts moral leadership can reduce these problems and lead the industry to better times.

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